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Fertilizers

In Relation to Soils and Crop Production

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IN RELATION TO SOILS AND CROP PRODUCTION

BY R. HARCOURT AND A. L. GIBSON.

INTRODUCTION.

On our comparatively new lands, and in general farm practice where a judicious rotation of crops is followed, and where grain is fed on the farm and the manure properly cared for, it may not be necessary to use commercial fertilizers; but where the nature of the crops grown prevents rotation, and where very little farmyard manure is produced, they may be required. More and more each year it is found that the increased cost of production and the consequent need of producing maximum crops, and the growing demands of the larger towns and cities for garden and fruit products of high quality, are causing market gardeners and fruit growers to consider seriously the advisability of using some form of fertilizer. This has created a demand for information concerning these substances which it has not been easy to fill; for experience has shown that the farmer must possess a wide knowledge of plants, soils, and the fertilizers themselves before he can properly use them.

To intelligently and economically use fertilizers, it is essential that the farmer understands the needs of the crops, their power to gather the essential plant food constituents from the soil, and the purpose of their growth, i.e., whether the object is to produce an immature plant for early market, or whether maturity is required. He must also know something about the available supply of plant food in the soil and the nature of the fertilizer being used. These fertilizers are expensive, and unless they are intelligently applied in conjunction with very thorough cultivation they will not give their best results. They cannot take the place of cultivation; for they are food materials, and can only aid the growth of the plant as they are absorbed by the roots, and these cannot develop fully in a poorly cultivated soil.

Because of the wide variation in the amount of available plant food in soils, the differences in the needs of plants, and the necessity of the farmer gaining some definite information regarding the nature of the fertilizers he is using and

the effect of these upon crops grown, we strongly recommend those who contemplate using fertilizers to commence in a small way and prove for themselves whether they can or cannot use these substances with profit. The object of this bulletin is to point out some of the main features regarding plants, soils, and fertilizers, which should be known in order that the work may be done intelligently, and to indicate briefly how experimental plots may be arranged to show whether special fertilizing materials are or are not required.

THE PLANT.

Most young plants start from a seed, which contains an embryo, or germ, that is extremely rich in albuminoids, fat, phosphates, and potash. The seed also contains a store of food, in the form of starch, fat, etc., intended to nourish the young plant until the roots and leaves are sufficiently developed to gather their own supplies. The future health and vigor of the plant will depend on: (1) the amount of food available to the tiny rootlets sent out by the young plant; (2) the temperature of the soil, (3) an abundance of sunshine, and (4) a sufficient supply of oxygen. The plant requires oxygen for respiration, and it gives off carbon dioxide as a result of the oxidation of its food, that is, it breathes; it gives off water from its leaves, or lungs, it assimilates food, and it even excretes waste material. In all this it is very similar to the animal. But it even goes further, and collects its food from the simple substances, such as carbon dioxide, and various soluble salts found in the soil, and from these builds up the complex sugars, starches, fat, and albuminoids which are essential for the life processes of the plant and which are the only foods of the animal. It is subject to improvement by selection and breeding, as is the animal, but, unlike the animal, it is entirely dependent upon the supply of food constituents within its reach, and it has no way of drawing attention to its wants, excepting as its appearance may make them known to the careful and trained observer. A clear conception of the fact that an infant plant, like the infant animal, requires warmth, air, sunshine, and an abundance of easily absorbed food, will greatly aid in understanding the conditions under which it will make the best growth.

Food of Plants.

The plant's food is derived from the atmosphere and from the soil. From the atmosphere it gathers carbon dioxide and oxygen, and some plants, through outside agencies, are able to collect nitrogen. Nearly fifty per cent. of the dry matter of a plant is made up of carbon which is entirely derived from the carbon dioxide of the air. Although this compound forms but 3 or 4 parts in 10,000 parts of the atmosphere, the quantity is sufficient, owing to the wind continually bringing fresh supplies to the leaves. Thus there is an abundance of air around the leaves of the plant, but, if the soil is not open and porous, there may not be enough in contact with the roots, for it is worthy of note that air in the soil in which crops are growing is as essential to the life of plants as air in the stable is to the animal. This ventilation of the soil is necessary to supply oxygen required in germination of seed, to permit the roots to live, for they, too, must breathe, and to supply this life-giving element to the millions of little organisms

in the soil which are busy preparing soluble food for the plant. The ventilation of the soil is also required to supply free nitrogen for the use of nitrogen-fixing germs, and to remove the excess of carbon dioxide which is being continually set free in the soil.

From the soil the plant derives nitrogen, chiefly in the form of nitrates, the ash substances, and water. Fortunately, although ten elements are essential for the growth of the plant, there are only four that particularly interest the farmer, as the other six are usually found in abundance. These four are, nitrogen, potassium, phosphorus, and calcium. A continuous supply of all the essential elements of plant growth is absolutely necessary; for, if one constituent is absent, or present in an insufficient quantity, no matter what amount of the other nutrients may be available, the plant cannot be fully developed. Consequently, just as a chain is only as strong as its weakest link, so the crop-producing power of a soil is limited by the essential nutrient present in relatively the smallest quantity.

Function of Plant Food Constituents.

In the absence of *nitrogen* the plant makes no appreciable growth. With only a limited supply, the plant commences to grow in a normal way, but as soon as the available nitrogen is used up, the lower and smaller leaves begin gradually to die down from the tips and all the plant's energy is centered in one or two leaves. Nitrogen is one of the main constituents of protein, which is possibly the most valuable part of a plant. It is also a constituent of chlorophyll, the green coloring matter of plants; hence with a limited supply of nitrogen, the leaves will have a sickly yellow color. Plants with large, well-developed leaves are not suffering for nitrogen. An abundance of this substance will produce a luxuriant growth of leaf and stem, but it will retard maturity, and, with cereals, will frequently cause the crop to "lodge." Therefore, when crops such as cereals, tomatoes, potatoes, etc., are to be matured, an over supply of nitrogen is injurious; but with the crops such as lettuce, cabbage, etc., which are harvested in the green condition, an abundance of nitrogen will, other fertilizing constituents being present, tend to produce a strong vigorous growth, and give crispness or quality to these crops.

Potassium, or potash, as it is commonly called, is one of the most important and least variable of all the elements of the ash of plants. It is quite evenly distributed throughout the leaves, stem, and seed, and generally occurs in the entire plant in the largest proportion of any of the essential ash constituents. The function of potassium is apparently to aid in the production and transportation of the carbohydrates. The flavor and color of fruits is generally credited to potassium. In fact, this element seems to supplement the action of nitrogen by filling out the framework established by the latter. Potash with nitrogen is always an important fertilizer with special crops where the object is to produce sugar, starch—as with sugar beets and potatoes. It is also apparently essential for the formation of protein, and, thus, indirectly aids in formation of all organic matter.

Phosphorus, in the form of phosphates, is found in all parts of the plant, but tends to accumulate in the upper parts of the stem and leaves, and particularly in the seed. Its function is apparently to aid in the production and transportation of the protein. It also seems to aid the assimilation of the other plant food

elements. An insufficient supply of phosphoric acid always results in a poorly developed plant, and particularly in a poor yield of shrunken grain. Nitrogen forces leaf and stem growth, and phosphoric acid hastens maturity.

Calcium, or lime, is a constituent of the stem rather than the seed, and seems to impart hardiness to the plant. It has been noticed that soils containing an abundance of lime usually produce well nourished crops that are capable of withstanding unfavorable climatic conditions, as drouth and early frosts, better than are crops not so well supplied with lime. The exact function of lime is not clearly understood, but it seems to aid in the construction of the cell walls. According to some authorities, its absence is felt in less time than either potassium or phosphorus. It is claimed that a supply of lime is just as essential to the plant in order that it may form cell walls from sugar and starch, as it is for the formation of bone in animals. It also has a very decided influence on the mechanical condition of the soil, and is a liberator of plant food, particularly potash, held in insoluble forms in the soil.

There can be little doubt that a proper balance in the supply of these four important plant nutrients has a very decided influence on the nature of the plant produced. Each has its own particular work to do, and the absence or deficiency of any one of them will cause the death or the incomplete development of the plant. Moreover, they are absorbed during the early stages of growth; for a cereal crop contains at the time of full bloom all the nitrogen and potash which is found in the mature plant; the assimilation of phosphoric acid continues somewhat later. It is thus plain that crops require a good supply of these important constituents of plant growth in a readily available form if they are to make a proper development.

Differences in Food Requirements.

Again, plants, like animals, differ very much in their requirements and in their ability to secure that which they need. Cereal crops contain much less nitrogen than legumes, but they have more difficulty in securing it. The autumn sown cereals have both deeper roots and longer period of growth than those sown in the spring, and consequently are better able to supply themselves with the necessary ash constituents. The spring tillage for barley, oats, and garden crops aid nitrification in the soil, therefore these crops have less difficulty in securing nitrogen. Barley, however, has a very short period of growth and is shallow rooted and cannot rustle for its food to the same extent as oats. Corn and the root crops are not only spring sown, but have a much longer period of growth than the cereals, and will thus have command of the nitrates produced during the whole summer. They have fairly good root development, but may not always secure all the potash and phosphoric acid required for the production of a full crop.

The striking characteristic of all the legumes is the large amount of nitrogen, potash, and lime found in them. However, although they contain fully twice as much nitrogen as the cereals, because of the power they possess of making use of the free nitrogen of the atmosphere, they have comparatively little difficulty in securing the required amount. On the other hand, they have difficulty in collecting potash. Consequently, it may sometimes happen that legumes suffer for want of this constituent on the same soil that cereals would find an abundance.

It will thus be seen that plants differ widely in composition, range of root, period of growth, and in their ability to gather that which they need from the

soil. These are facts which a farmer should be familiar with in order that he may intelligently manure the soil and plan the rotation of crops he wishes to follow in a manner that will give the best possible results.

THE SOIL.

But a knowledge of the plant and its requirements alone is not sufficient. It is very important that the farmer should know something about the constituents of the soil and the manner in which they may be brought into solution.

Soils are formed from rock by the prolonged action of water, frost, and air, combined with that of vegetable and animal life and their products. It is not necessary to go into details regarding the action of these various agencies. It is sufficient to point out that through their combined action, extending over thousands of years, the rocks have been broken down and their materials more or less separated by water into gravelly, sandy and clayey soils, and all the mixtures of these so commonly found throughout the Province. In these soils there is practically all the potash and phosphoric acid that was present in the original rocks. They are differently distributed, as, for instance, clays are richer in potash than sands; but the rocks are the sole source of the natural supply of these and all the other ash constituents essential for the growth of plants.

DRAINAGE.

It must not be forgotten that the soil is the home of the plant, and if the plants are to make good growth, the home must be congenial. The factors that make it so are an abundance of readily available food, water, air, and a suitable temperature. To secure this good drainage is of primary importance. No soil can be warm or well aerated that is full of water. Nor will the organisms that bring about the decay of the organic matter exist in such a soil. Hence, good drainage must precede all other work in endeavoring to get the maximum results from the soil.

DECAYING ORGANIC MATTER.

Nitrogen is derived from the air and is incorporated into the soil largely by means of plants. Consequently, the natural richness of a soil in nitrogen is almost entirely dependent upon the amount of decaying organic matter present. Through careless cultivation, this original supply of nitrogen may be depleted; or by growing plants, particularly legumes, the nitrogen gatherers, it may be increased. There is an almost unlimited supply of nitrogen in the atmosphere, and man has been given the means of gathering this and incorporating it in the land. As a result, the amount of this element in the soil, more than any other plant food constituent, is within the control of the farmer. Moreover, the addition of organic matter to a soil has a very much wider bearing than the simple addition of nitrogen; for, in its decay the vegetable acids and the carbon dioxide formed tend to bring the insoluble potash and phosphoric acid into an available form. Humus, which has such a wonderful effect on the mechanical condition of the soil, and which so increases its water-holding capacity, is also a product of the decay of organic matter. In fact, the presence of an abundance

of decaying organic matter is practically indispensable. It is the source of nitrogen; the acids liberated in its decay make available the important ash materials which would otherwise be useless; it warms the soil; increases its capacity to hold water needed to dissolve the plant food; and improves its physical condition. Without the presence of organic matter and the associated germ life and the proper conditions for their action, a soil cannot produce its best results, no matter how rich it may be in all the essential constituents of plant growth.

LIME.

Lime materials not only furnish calcium, which is essential for the growth of crops, but they have the power of improving the mechanical condition of both sands and clays. This they do by binding the materials more firmly together. In the case of sands, lime thus renders them more compact and improves their water-holding power. With clays, the tenacity of which is largely due to the fineness of the particles, the lime causes the fine particles to adhere to one another, and these aggregations make the soil act like one composed of larger particles. Hence, it improves the mechanical condition, renders the soil more easily cultivated and it is better aerated. Frost and humus also improve the physical state of sticky, impervious soils; but lime is possibly the most potent agency, and it is certainly the agency most readily controlled by the farmer.

Lime also corrects, or neutralizes, the acid which naturally forms in soils, especially those rich in decaying organic matter. Experience and investigation show that many of the soils of this Province are gradually being depleted of their natural supply of lime, leaving them in an acid or "sour" state, which is detrimental to the development of many crops, and absolutely prevents the growth of alfalfa, clover, or the plants of the leguminous family in general.

Lime materials are also necessary for the useful and beneficial bacteria and other organisms of the soil. They supply these organisms with the element calcium, which appears to be just as essential a food constituent for them as it is for the higher plants. Furthermore, in improving the physical state of the soil, lime produces good air and moisture conditions which are so essential to the well-being of these organisms upon whose activity the availability of the plant food in the soil so largely depends. Thus it will be seen that decaying organic matter and lime are very important constituents of soils. In fact, their presence is fundamental. Without these the soil is practically useless no matter how much other plant food may be present. In one sense it may be correct to speak of the soil as a reservoir of plant food, to be drawn on for the growth of successive crops, but it is equally correct to regard it as a busy, complex manufacturing establishment in which all the various parts must work together under proper conditions to bring the store of plant food into a form available to plants. To bring this about is the object of cultivation.

LOSSES OF PLANT FOOD BY LEACHING.

These combined agencies, while beneficial, are destructive unless means are taken to prevent loss by drainage. They tend to bring nitrogen, lime, magnesia, potash, etc., into a soluble form, which, unless taken up by plants, is lost in the drainage water. As proof of this, we have the familiar fact that water taken from underground drains or from wells is "hard" because of the lime which it

holds in solution. Consequently, a surface soil is generally poorer in lime, and frequently in potash, than the subsoil. The complete impoverishment of the soil is prevented by the presence of certain constituents which combine chemically with the liberated plant food substances, and by the conservative action of vegetation. The plant is continually collecting from the soil and subsoil dissolved or easily soluble matter, storing these in its tissues, and at its death leaving them in the surface soil. But even with the best of management there is some plant food leached from the soil.

However, according to a well known law, Nature allows nothing to be lost, and these leached-out materials are, through various agencies, at least partially, made to accumulate in great beds of limestone, phosphatic rock and potash salts. It is these accumulations of past ages that are to-day furnishing the main constituents of fertilizers. Who knows but what the plant food which is being annually leached from our fields will come into use in future ages.

Losses of Plant Food in Crops.

But the leaching away of plant food is not the only way in which these materials are lost from the soil. The vegetable and animal produce of the land are frequently consumed off the land which reared them. A partial return of the plant food thus taken from the soil is made by the application of farmyard manures, but the sale of vegetables, fruit, grain, animals, and animal products, the congregating of men in towns and cities, and the difficulty in employing sewage with profit; and the loss of fertilizing constituents from farmyard manure before it is applied to the land, all tend to make the return of the manurial constituents to the soil incomplete.

Some soils are naturally so rich in the elements of plant food that when the crops are properly rotated and "catch" crops used to economize this natural wealth of fertilizing constituents, it may be a long time before the soil needs special manures; but, if the land is naturally poor, or injudiciously cultivated, or if special crops of like nature have to be grown year after year on the same ground, it may soon need some extra manure.

On naturally poor soils it may be necessary to make a complete return of all the elements of plant food removed by crops; but in most soils there is an abundance of some one or more of these elements, and a partial manuring will consequently suffice. With intensive farming, where thorough cultivation is practised, a good system of rotation followed, where little grain is sold and some food is purchased in its place, and every care taken of the manure, the land may even gain in fertility. These, however, are not the conditions which exist with the gardener and fruit grower, and they must of necessity purchase manure of some kind.

MANURES.

Manures may be defined as anything that when added to the soil increases the amount of available plant food in a reasonable length of time. Generally speaking, they may be divided into two classes: general and simple manures.

The *general* manures include farmyard manure, the various products of the abattoirs, and substances of vegetable origin. These materials not only furnish

plant food, but contain varying quantities of organic matter. The *simple* manures supply only one plant food substance and constitute what are generally known as the mineral fertilizers.

Farmyard Manure.

Farmyard manure is the most popular manure on the farm. Its action is three-fold: First, it supplies plant food; second, it supplies organic matter, the importance of which has been referred to in a previous paragraph; and, third, it possibly serves as the main source of supply for the re-seeding of the soil with those desirable organisms which bring about decay in the soil. The composition of farmyard manure will vary according to the kind of animals contributing to it, the quality of the food, and the nature and proportion of the material used as bedding.

In the case of a full grown animal neither gaining nor losing in weight, a working horse for instance, the quantity of nitrogen and ash constituents voided in the manure will be nearly the same as that in the food consumed. In cases where the animal is increasing in size, is producing young, or furnishing wool or milk, the amount of nitrogen and ash constituents in the manure will be less than that in the food; that is, it will be in direct proportion to the quantity of these substances which has been converted into animal increase. Thus, with fattening cattle, sheep and with work horses more than 95 per cent. of the nitrogen and ash constituents in the food are voided in the manure. The pig retains a larger proportion of the nitrogen, but no more of the ash constituents. A milking cow retains a still larger proportion of the nitrogen and ash, but the best (yield) in animal increase is obtained in the case of a young calf, when 70 per cent. of the nitrogen consumed is built into new tissues of the body and only 30 per cent. excreted as manure.

The amount of nitrogen voided in the urine is always greater than the quantity contained in the solid excrement, and in the case of the fattening animals it may be three or four times as much. This will vary according to the diet. If the food is nitrogenous and easily digested a large proportion of the nitrogen will occur in the urine. If, on the other hand, the food is one imperfectly digested the nitrogen in the solid excrement may form a larger quantity. When horses are fed on poor hay the nitrogen in the solid excrement will somewhat exceed that contained in the urine, but when grains or other concentrates are fed there will be a large excess of nitrogen in the urine.

The ash constituents are quite differently distributed in the solid excrement and urine. In the former is frequently found nearly all the phosphoric acid and a greater part of the lime and magnesia, while the urine contains a greater part of the potash. Horse urine is the exception to the above rule as it contains a rather notable amount of lime.

It is evident, then, that if the urine carries such a large proportion of the nitrogen and potash it should be carefully preserved. The simplest and easiest way to accomplish this is to use plenty of bedding in the stall. In city stables sawdust and other woody materials are frequently used, and if dried are good absorbents. In the country, straw is still the most common absorbent, but on many farms where peaty materials are plentiful it might be well to use some of these dried substances to aid in the absorption, and increase the amount of nitrogen in the manure.

TREATMENT OF MANURE. The treatment of manure is very important. As stated above, the greater part of the nitrogen and potash are found in the urine, consequently, if the liquid is lost or the manure is washed with water and the liquids are allowed to drain away, serious loss of nitrogen and potash will occur. Again, it may also be pointed out that the nitrogen in the urine is largely in the form of urea, a compound that is speedily changed by fermentation into ammonium carbonate. This compound is volatile, consequently loss of nitrogen rapidly occurs, and chiefly, while the manure is still in the stable. German experimenters have pointed out that in the case of horses and cows the loss may amount to [illegible] per cent. of the nitrogen voided by the animal. The best way to diminish this loss is by liberal use of bedding so as to absorb all of the liquid. For this purpose dried peat would be especially valuable. This material is found in large quantities in many parts of the Province and in many cases might be very profitably used as an absorbent in the stable.

Farmyard manure readily undergoes decomposition; the nature of the products formed depend on the amount of air admitted or excluded. If the manure is thrown loosely into a heap it becomes very hot and rapidly wastes. The organic matter in this case is virtually burned, or is "firefanged" as it is commonly termed, and ammonia is one of the products lost. If, on the other hand, the manure is consolidated and kept thoroughly moist so that air is excluded, the mass ferments with very little rise in temperature, and nitrogen gas is volatilized. The loss of organic materials will be far less with this kind of fermentation than in the previous one, but in both cases nitrogen is given off from the manure. Experience proves that there is the least waste of manurial constituents when the manure is preserved in a box stall. It has been shown that a quantity of food and litter which in a box stall yielded 10 tons of manure containing 108 pounds of nitrogen yielded when carried daily to a heap only 7.5 tons, containing 64 pounds of nitrogen.

Undoubtedly, especially on heavy lands, the best returns from the manure are got when it is put on the land and at once plowed in. The losses that are inevitable when manure is stored would be prevented and a greater amount of organic matter added to the soil. Naturally, this is not always possible, but when the manure must be kept it should be made without delay into a solid heap or mass and must not be allowed to get dry. The practice is sometimes followed of drawing manure to the field during the winter months as fast as it is made. Provided the land is not too hilly, or too clayey, this will give good results. It must be noted, however, that this method does not prevent losses, but is recommended to economize labor. When the manure is drawn to a field and put in a big heap care should be taken to make the heap as firm as possible, and, theoretically, it should be covered with earth, but this under our conditions of labor is impossible.

The returns from the application of farmyard manure are not so quick as may be got from certain forms of fertilizers. This is because the materials must first decay before the plant can use them, which will take some time in the soil. The total amount of the three most important constituents in the manure will naturally vary with the conditions which have been mentioned. The nitrogen will vary between .45 and .65 per cent. or even higher if produced by highly fed animals. The amount of potash may vary between .4 to .8, and the phosphoric acid from .2 to .4. Thus, one ton of farmyard manure will contain from 9 to 13 or 14 pounds of nitrogen, 8 to 16 pounds of potash, and 4 to 8 of phosphoric acid. Possibly a good figure to carry in mind would be that one ton of manure

contains 10 pounds of nitrogen, 10 pounds of potash and 5 pounds of phosphoric acid.

Experience shows that no manures can quite take the place of the farmyard manure. It is what may be spoken of as the natural return to the soil of the constituents taken from it. All other substances are in a sense supplements, materials added to make good some special deficiency in the soil, or to supply some plant food constituent particularly required by the crop to be grown. Hence, the care and treatment of the farmyard manure is fundamental in all good agriculture.

Guano.

Guano is the dried dung of sea birds, together with portions of their feathers, bones and the refuse of their food. This material accumulates on islands or near the coast in tropical climates. The chief deposits have been found in North and South America, Africa, Australia, the West Indies and Islands of the Pacific. Some of the original deposits are now exhausted. Where the deposits of Guano have been got from rainless districts, or at least, where they have not been subjected to the leaching action of water, they are rich in nitrogen and may contain from 7 to 11 per cent. of nitrogen and 5 to 15 per cent. of phosphoric acid. Where they have been subjected to a leaching action, the amount of nitrogen is very much reduced, and as the phosphates are not soluble, these materials have increased in proportion. This makes the chief difference between the two forms of guanos that are brought into the country. There is, however, comparatively little of this material brought into Ontario, as most of the small supply which now remains is taken to the European countries.

One feature that has lent value to the guanos is that the nitrogen is largely in the amide and ammoniacal condition and is thus very quickly brought into an available condition. In this respect it stands next to the nitrates.

Dried Blood.

Dried blood from our large slaughter houses is frequently used as a manure. It is one of the richest of the organic nitrogenous materials in nitrogen and it is one of the best since its physical character is such as to permit of its very rapid decay in the soil during the growing season. It contains 9 to 12 per cent. of nitrogen and a small amount of phosphoric acid. Dried blood is frequently applied along with nitrate of soda when a fairly large continuous supply of the nitrogen is wanted throughout the growing season.

Dried Meat Meals, or Meat Guanos.

This material is another source of high grade organic nitrogen and consists of meat scraps, or of nitrogenous materials from the slaughter houses. When relatively pure it contains from 13 to 14 per cent. of nitrogen and thus compares favorably with blood.

Bones.

Bones form a very important manure, particularly on soils which show a deficiency of phosphoric acid or for crops that require considerable quantities

this constituent. They are valuable as they contain nitrogen and phosphoric acid. *Ground raw bones* may contain about 30 per cent. of organic matter, with perhaps 3 to 4 per cent. of nitrogen and about 20 per cent. of phosphoric acid. Raw bones, however, also contain considerable fat. This ingredient is objectionable since it hinders the decomposition of the organic matter after the bones are applied to the soil, and it also renders it practically impossible to reduce the bones to a finely divided condition before applying. For this reason, and also in order to extract gelatine, they are submitted to the action of steam under pressure and thus robbed of their fat and some of the gelatine and brought into a condition to be easily reduced to a fine state. This *steamed bone* meal will contain 1 or 2 per cent. or under some methods of extraction even more, nitrogen, with from 20 to 25 per cent. of phosphoric acid. The phosphoric acid is chiefly in the form of tri-calcic phosphate, which is insoluble in water; consequently, the finer the bones are ground the more rapidly the material will come into solution in the soil. Bones are particularly valuable for their phosphoric acid, and are usually classed as a phosphatic manure.

Tankage.

Tankage is a nitrogenous product and consists chiefly of dried animal wastes from slaughter houses. It varies somewhat in composition since it includes otherwise unsalable parts of the carcass, as bones, flesh, hair, hoof, horn, etc. The keratine substances do not decompose readily in the soil, consequently, while tankage may be approximately as rich in nitrogen as dried blood and meat meals, it is not so valuable because it does not give as quick returns. It usually contains a varying quantity of phosphoric acid.

Fish Manure.

The bodies of fish are highly nitrogenous and their bones contain large quantities of phosphates. Sometimes the refuse from the fish canneries is incorporated in these fish manures. In general, the most objectionable feature to them is the oil which they contain, as this hinders the fermentation and decay of the materials by repelling the water.

Naturally, this manure varies widely in composition. American dried fish refuse is said to contain about 7 per cent. of nitrogen and about the same amount of phosphoric acid.

Vegetable Refuse.

Certain forms of vegetable refuse, as oil cakes, husks, etc., which are left after the oil is extracted from certain seeds are sometimes used as a fertilizer. These materials are frequently highly nitrogenous and contain a considerable quantity of phosphates and potash. Some of them decompose slowly in the soil and are not quick acting manures. These materials are usually used as cattle feeds, but in some cases owing to the presence in the seed of poisonous or unpalatable substances, they are used in the making up of certain forms of fertilizers. They may contain as much as 5 per cent. of nitrogen, 1 to 2 per cent. of potash and 2 to 3 per cent. of phosphoric acid.

Simple or Mineral Manures.

Besides the organic materials which have been discussed, we have a number of other substances, generally of mineral or artificial origin, which are employed as fertilizers. These may be divided into nitrogenous, phosphatic and potassic.

Many of the organic materials already described contain variable quantities of the chief manurial substances, but those about to be dealt with are as a rule intended to supply only one important element of plant food. Their use makes it possible for the farmer to apply one or more elements of plant food that may be necessary on his farm, and thus obviates the need of purchasing other elements which he may not require.

NITROGENOUS FERTILIZERS.

Although four-fifths of the atmosphere is nitrogen and thousands of pounds of this element are over every acre of land, it is the most costly plant food substance. As has been pointed out, the growing of leguminous plants makes it possible for the farmer to gather some of this immense supply. Hence, the more the leguminous crops are introduced into the rotation, the more this free nitrogen is incorporated into the soil. Through this agency the soil may be enriched in nitrogen, and every effort ought to be made to gather some atmospheric nitrogen and thereby reduce the amount that has to be provided from other sources.

The most important nitrogenous fertilizers are: nitrate of soda, sulphate of ammonia, and calcium cyanamid. These are all soluble in water, and should be used as a direct food to the plant and not to build up a reserve in the soil.

Nitrate of Soda.

Sodium nitrate (nitrate of soda, Chili saltpetre) occurs in enormous deposits in Peru and Chili. It is found in rainless districts and comparatively near the surface. The raw material is found beneath a covering of sand, gypsum, clay and gravel, which is usually removed with the aid of gunpowder. The crude material thus exposed varies from a few inches to 12 feet in thickness and is broken up and carried to the refinery where it is purified by crystallization. The material is then put up in sacks containing 200 pounds and in this form is shipped to all parts of the world. The product supplied for agricultural purposes contains approximately 95 per cent. of real sodium nitrate and consequently yields about 15.6 per cent. of nitrogen. It is extremely soluble and diffusible and is at once available to plants, hence the greater part should be applied when the crop is sufficiently grown to be capable of assimilating it, otherwise, since it is not retained by any constituent of the soil, considerable loss in drainage may occur.

Ammonium Sulphate.

When organic nitrogenous substances are submitted to destructive distillation, that is, heated strongly without access of air, the nitrogen which they contain is to a large extent expelled as ammonia. Therefore, when coal is heated by destructive distillation in the preparation of coal gas the nitrogen which it con-

..aporized in the form of ammonia. Ammonia is also got in the same ... from coke ovens, and to some extent in the preparation of producer gas ... water gas. The ammonia thus secured is passed into sulphuric acid and ...um sulphate is formed. This crude material is then more or less purified ... under the name of "Ammonium Sulphate." In the form in which it ...d as a fertilizer it usually contains about 20 per cent. of nitrogen.

Ammonium sulphate is not so quick in its action as nitrate of soda, because ... undergo nitrification, or change into nitrates, before it can be absorbed. ...nce of calcium carbonate is essential for this change, consequently, it ... be applied to soils deficient in lime, and furthermore, its use is ... associated with a rapid depletion of the soil in lime. Nitrate of soda ... applied in several small dressings during the growth of the plant, whereas ...um sulphate may be applied at once, even before the crop is sown, without ...s, because in various ways it is retained by the soil. The usual quanti... ... either of these materials applied is from 100 to 200 pounds to the acre ... such crops as mangels and potatoes and many garden crops larger ...ties may be used.

Calcium Cyanamid.

Calcium cyanamid is one of the newer forms of nitrogenous manures. It ... prepared by heating calcium carbide to a very high temperature by electricity and passing the nitrogen of the air over it. The resulting compound is somewhat bluish black in color and contains about 15 per cent. of nitrogen. It also contains calcium equivalent to 70 per cent. of slaked lime. Many of its former disadvantages are being overcome and it will doubtless become one of the most valuable of our nitrogenous manures. At present it is used principally as a constituent of mixed fertilizers.

Calcium Nitrate.

Calcium nitrate is another of the newer products in which the nitrogen of the atmosphere is put into a commercial form. Little or none of this compound has been used in this country, although it is becoming a somewhat common ... of commerce in some parts of Europe.

Nitrogen in the Organic Form.

Considerable difference of opinion exists as to the value of organic nitrogen. ... a purely plant food standpoint, organic nitrogen has no higher value than ...ailable nitrate nitrogen, since it must be changed into the nitrate condition ...fore it can be assimilated by the plant. The value of organic nitrogen as a ... food compared with quickly available forms lies in the fact that as it ...ually decomposes, it forms a gradual supply of available nitrogen to the grow... plant over a long period. It should be remembered, however, that many organic ... manures are so complex that their decomposition is extremely difficult and they are of little service to increase the crop yield. Among these slowly available nitrogenous substances may be mentioned rags, hair, skin, horn, crushed ...s and leather. Of the more valuable and easily rendered available forms of organic nitrogen may be mentioned feeding cake refuse such as rape cake, dried

blood, tankage and wool waste. The value of organic material in improving the physical nature of soils is a well established fact, but to buy large quantities of nitrogenous organic fertilizer as a source of organic matter to the soil cannot be considered economical. Farmyard manure is a cheap source of organic matter, but where it cannot be produced its place may be taken by growing a catch crop of rye, mustard or clover ready to be plowed under as green manure.

In brief, we may say regarding the three forms of nitrogen that if during a rotation a quick result is needed within one season a supply of nitrate and ammonia nitrogen will be most effective. On the other hand, if the effect of the manure is required only after considerable time and then a gradual supply is needed, organic nitrogen would be most suitable.

PHOSPHATIC MANURES.

Several materials are used as a source of phosphoric acid. Chief of these are superphosphate, bone meal, ground rock phosphate, and basic slag. The bone meal has been referred to under organic manures and need not be discussed here.

Ground Rock Phosphate.

This material differs from those of animal origin mainly in the fact that it is not combined with organic matter and is more dense and compact in its structure. The phosphate is got in South Carolina, Florida, Tennessee and some of the Eastern Provinces of Canada. It varies in composition, but contains from 25 to even 40 per cent. of phosphoric acid (P_2O_5). The phosphoric acid in this material is in the form of the tricalcic phosphate, and therefore insoluble in water, and is very slowly rendered available. Fine grinding is the means used to increase the solubility. Dependence is placed upon the acids formed by the decaying organic matter to bring this material into solution.

Basic Slag.

Basic slag, or Thomas phosphate, is a very finely ground, heavy black powder. It is a by-product in the manufacture of steel from iron and contains from 12 to 20 per cent. of phosphoric acid (P_2O_5). The availability of the phosphoric acid in the crude basic slag varies greatly, even as much as from 20 to nearly 100 per cent. Consequently, care must be exercised in the selection of the material that is to be prepared for use as a fertilizer. The better forms on the market contain from about 11 to 13 per cent. of available phosphoric acid. This is in the form of tetra-calcic phosphate, which appears to be more soluble under soil conditions than the tri-calcic phosphate. The standard for fineness is that 80 per cent. of the material should pass through a sieve with 10,000 openings to the square inch.

Superphosphate or Acid Phosphate.

Years ago, when phosphoric acid was recognized as an essential plant food constituent, bone meal was the chief source of this material. To increase its availability the bones were ground to a very fine powder, but even this did not

is not quick enough in its action. To improve it in this respect a method was introduced whereby the most of the insoluble tri-calcic phosphate of bone was changed into soluble mono-calcic phosphate. This was accomplished by treatment with sulphuric acid and the product became known as superphosphate or acid phosphate. Gradually the cheaper rock phosphate has replaced the bone meal in the preparation of the acid phosphate, until to-day comparatively little of the bone meal is being used for this purpose. The bone in the finely ground condition is really too valuable applied direct to be used in this way, especially as the tri-calcic phosphate of the rock material treated with the sulphuric acid becomes just as available a form of plant food as would be got from the bones. Most of the superphosphates on the market contain about 14 to 16 per cent. available phosphoric acid. The chief advantage of this material over the undissolved forms is that the phosphoric acid is quickly available. Basic slag cannot be used for this purpose because it contains a large amount of iron, and under the treatment with sulphuric acid phosphoric acid would be converted into the iron phosphate, which would be much more insoluble than in the form in which it was originally held. The ground bone and basic slag are not quick enough in their action to fully meet the needs of quick growing crops, but may be used with such crops as grow through long periods, as meadows, orchards, vineyards, etc. The rock phosphate will be still slower in its action, and should be applied to soils that are fairly rich in organic matter, because under these conditions the phosphoric acid may be brought into solution by the acids which are formed in the decay of the organic matter. Basic slag should also be applied to soils rich in organic matter, or even to those which have a tendency towards sourness, as it contains a considerable amount of lime.

Superphosphate, on the other hand, should never be applied to soils that are inclined to be sour, because it is of an acid nature. The chief advantage of the superphosphate over the other forms is that it contains soluble phosphate which dissolves on being placed in the soil, and is thus more evenly distributed through the ground than can be done by mechanical distribution. In a longer or shorter time it is reverted to the insoluble form in which it was originally, but in the meantime it has become so distributed through the ground that the roots can come more in contact with it and it is better absorbed.

POTASH MANURES.

Until the discovery of the potash mines in Germany in 1860, wood ashes were the chief source of this constituent as a fertilizer. To-day, practically all potash salts used in the world comes from the famous mines in Germany. It is placed on the market in a variety of forms, but the chief materials that reach this country are kainite, muriate of potash and sulphate of potash.

The *kainite* is a crude salt containing about 12.5 per cent. of actual potash, which is largely in the form of the sulphate. Along with it, however, there are large quantities of ordinary salt and small percentages of chloride and sulphate of magnesium. Freight rates make it almost prohibitive to bring this product inland.

Wood Ashes.

Wood ashes are valuable as a source of potash and previous to the op... of the potash mines in Germany were very much sought after. Good unleache... ashes should contain at least 5 or 6 per cent. of potash and from 1.5 to ... per cent. of phosphoric acid (P_2O_5). The potash is is an excellent form to serve as a plant food and is immediately available. Valuing the potash at 5 cents per pound, which is about the cost of it in sulphate of potash, wood ashes are wo... 25 to 30 cents per hundred, or $5 or $6 per ton for the potash alone. But ... also contain some phosphoric acid, and 25 to 50 per cent. of the whole of ... material is carbonate of lime.

Leached ashes are ashes that have been exposed to the weather and usuall have lost all but about one-half of one per cent. of their potash. The phosphor... acid and lime, however, remain unchanged.

Muriate of Potash.

Muriate of potash or potassium chloride is more generally used than any of the other salts. It varies somewhat in composition according to the method of manufacture, but the product most commonly met with in this country contains about 50 per cent. of actual potash. The chief impurities are common salt, and certain insoluble matters which are not injurious. All the potash in this material is immediately available.

Sulphate of Potash.

This salt is usually from 90 to 95 per cent. pure and therefore contains an equivalent of from 48 to 51 per cent. of actual potash. It is preferable to the muriate for certain crops. Thus, the muriate is not recommended for potatoes, sugar beets and tobacco. The sulphate, however, costs from $7.00 to $10.00 per ton more than the muriate. Possibly if the muriate of potash were applied some time before planting the ill effects attributed to this material might be overcome. The potash manures may be applied some time previous to the seeding or planting, but should not be plowed down. They react with other compounds in the soil and are fixed or so firmly held by the soil constituents that there is no fear of heavy loss by leaching. Early applications give the material a chance to become diffused through the ground so that it can come in contact with the roots as they spread themselves throughout the soil.

LIME.

The chief forms in which lime is used to-day are: quick lime, carbonate of lime and marl. Hydrated lime is slaked lime screened and is too expensive to use for liming soils. Air-slaked lime is a mixture of slaked lime and carbonate of lime. The amount of the latter substance present is dependent upon the length of time the lime has been exposed.

Quick Lime.

[illegible] lime, or fresh burnt lime, is more active than the carbonate and, [illegible] where there is a great deal of acid to neutralize, it may be preferable [illegible] forms. It hastens the decay of the organic matter. On deep swamp [illegible] may be a decided advantage, but on light arable soil it may be a dis[illegible] Unless there is a large amount of acid to neutralize, it should not [illegible] at heavier applications than about a ton per acre. This may be dropped [illegible] the field at convenient distances for spreading, covered with a little [illegible] to slake, and then spread with a shovel. It should not be plowed [illegible] thoroughly worked into the soil by surface cultivation.

Marl and Carbonate of Lime.

[illegible] rich in carbonate of lime and may contain traces of phosphoric acid. [illegible] marl beds in this Province are associated with our swamp lands. The [illegible] of lime is simply ground limestone rock. Some experiments seem to [illegible] that the dolomite rock is more valuable as a fertilizer than the purer [illegible]. To secure quick results limestone should be finely ground. We [illegible] however, large quantities of dust from the stone crushers preparing stone [illegible] making that is very suitable for this work. It is not all fine enough to act [illegible] but nearly 50 per cent. of it will pass through a sieve with 10,000 open[illegible] the square inch. This material can be procured at 50 cents per ton in [illegible] lots. The freight charges will, in many cases, be greater than [illegible] cost [illegible] materials; consequently, as it can be procured in a number of [illegible] in [illegible] Province, care should be exercised in purchasing at the nearest point and [illegible] reduce the cost of transportation. In applying ground limestone rock it [illegible] to remember that it takes practically two tons of this material to supply [illegible] calcium as one ton of quick lime. The ground rock is not so active [illegible] the quick lime and therefore may be applied in very heavy quantities without doing any harm.

Gypsum.

[illegible] land plaster, or sulphate of calcium, exerts a similar effect to that [illegible] in improving the mechanical condition of clay soils. It serves as a source [illegible] calcium as a plant food, and it serves to stimulate the beneficial soil organisms [illegible] roots of leguminous plants like the clovers, alfalfas, peas, beans, etc. In [illegible] ways it acts in the same manner as lime, but gypsum will not, like lime, [illegible] or neutralize the acid of a soil. Nor does it hasten the decay of organic [illegible] as does the quick lime. As an aid to the growth of the legumes it may [illegible] at the rate of 300 to 500 pounds to the acre. If used to "lighten," [illegible] the physical condition of clay soils heavier applications will be [illegible].

Salt.

Agricultural salt was formerly used in this Province in considerable quantities, [illegible] of late years very little has been applied. It supplies no essential plant food [illegible] and its value appears to be due to indirect action, and thus it acts more as a stimulant.

HIGH-GRADE FERTILIZERS.

Fertilizers may also be divided into high-grade and low-grade materials. Nitrate of soda, sulphate of ammonia, and dried blood are, for example, standard or high-grade nitrogenous materials. They are so classified because they are fairly constant in composition and furnish nitrogen in some constant and definite form, which will act the same under like conditions. Further, they are rich in nitrogen and the element is immediately or quickly available to the plant. Ground rock phosphates differ in this respect from the above mentioned nitrogenous substances, because, in the raw state, the phosphoric acid for which they are valued though present in large quantities and quite constant and definite in its form of combination, is not available to plants. After it has been treated with sulphuric acid and converted into superphosphate it is high-grade, owing to the fact that the phosphoric acid has been rendered available.

The various German potash salts, such as muriate of potash, sulphate of potash, etc., are also high-grade, since the composition of each grade and kind is practically uniform in its content of potash, which will always act the same under all conditions, and since they are richer in potash than any other potassic compounds suitable for making fertilizers.

LOW-GRADE FERTILIZERS.

The products which are included in the second class differ from the first, in that they may not only vary in their composition, but the constituents contained in them do not show a uniform rate of availability. Different samples of bone derived from the same source, treated in the same way, and ground to the same degree of fineness, would be high-grade, but because these conditions differ, bone from various sources cannot be depended upon to act the same under similar climatic and soil conditions. The same is true of tankage; but it varies also in the proportion of its two main constituents, nitrogen and phosphoric acid, and in the rate at which they become available to plants. In this class we must also place fish scrap, wood ashes, and the miscellaneous substances that may be used in building up mixed or complete fertilizers.

GUARANTEES.

It is, therefore, evident that mixed fertilizers manufactured from these two classes of raw material differ in value; for the nitrogen from nitrate of soda or dried blood will act quicker and is worth more than that from ground leather or horn. In the making of the ordinary complete fertilizers of commerce, in which nitrogenous, potassic, and phosphatic materials are all mixed together, it is impossible for the purchaser to judge of the nature of the materials used by the appearance, weight, or smell of the mixture, and, furthermore, he can form no idea of the probable amount of plant food constituents present.

To aid in the intelligent purchase of fertilizers the Dominion Government have enacted a law whereby it is made illegal for any manufacturer or manufacturer's agent to offer for sale any fertilizer without giving a guarantee of the

[illegible] plant food constituents contained therein. According to our present [illegible] Act "Every brand of fertilizer offered for sale in Canada shall bear a [illegible] number, which shall be permanently assigned to the particular brand [illegible] of fertilizer for which it is issued. The number shall be granted by [illegible] on the application of the manufacturer of such brand of fertilizer, [illegible]nt, and on payment of a fee of two dollars."

[illegible] registration number must be affixed by the manufacturer, or agent, [illegible] and legible manner, to every package of fertilizer sold or offered for [illegible] shall constitute an identification of the brand. In addition to the registra-[illegible] there must be legibly printed, on every package of fertilizer sold, the [illegible] set out in Schedule A to this Act. This condition shall be held to [illegible] if a printed tag, bearing the registration number and the statement [illegible] is securely attached to the package."

"[illegible] purchaser of a registered fertilizer may obtain from the Minister an [illegible] of the fertilizer as delivered to him, by making application for such [illegible] accompanied by a sample of the fertilizer of at least one pound weight, [illegible] in accordance with the directions given in Schedule B to this Act, and [illegible] payment of a fee of one dollar.

"If any fertilizer is imported for the personal use of the importer, and not [illegible] this Act shall not apply thereto, but such importer may secure an [illegible] of the fertilizer, as delivered to him, on application to the Minister and [illegible] of a fee of five dollars. The sample submitted must be taken in [illegible] with the requirements of section 10 of this Act."

SCHEDULE A.

Statement to be attached to package.

1. (Name of brand.)
2. (Registration number.)
3. (Name and address of manufacturer.)
4. (Analysis, as guaranteed by the manufacturer.)
5. Notice. Any purchaser may have an analysis made by the Department of Inland Revenue on payment of one dollar. Samples must be taken in conformity with the regulations. For regulations address the Deputy Minister of Inland Revenue, Ottawa.

SCHEDULE B.

Instructions for taking samples of fertilizers to be submitted for analysis in accordance with Section 10.

"Samples of fertilizer submitted by a purchaser for analysis must be inclosed in glass [illegible] or bottles, and properly sealed. The samples must be taken in the presence of the vendor or of his representative.

Process of Sampling.

"[illegible] of five tons, or less, portions shall be drawn from each separate package, [illegible] at least ten packages; or if less than ten packages are present, all shall be [illegible] In lots of over five tons, at least ten per cent. of the packages shall be [illegible] The portions so taken shall be thoroughly mixed in the presence of the parties [illegible] and from this mixture the sample sent to the Minister is to be taken; [illegible] bear the signature of vendor and purchaser; and at the same time a duplicate sample is to be left with the party whose goods are inspected, subject to the call of the manufacturer or agent."

[illegible]mpelling the manufacturer to guarantee the amount of plant food in [illegible], the Government have done what they can to aid the farmer to purchase intelligently. But to make use of this data the purchaser must be familiar with

the terms used and know the commercial value of the different plant food constituents.

Statement of Guarantee.

The statement of a guarantee should be as simple as possible. All that is required is the per cent. of nitrogen, potash and available phosphoric acid. The amount of insoluble phosphoric acid may also be given, but as little value is placed on this part of the material it is not important. Sometimes, however, the per cent. of nitrogen is given and its equivalent of ammonia. This is simply two ways of stating the same fact. Again, phosphoric acid may be quoted in terms of "water soluble," "citrate soluble," "available," "insoluble," and "total." Out of all of these statements the only one that is required is the "available," or, if we want to know the amount of other forms of phosphoric acid, the "insoluble" may be included. The potash is also very often stated in two ways, as "potash" or as "equal to sulphate of potash." This again is a statement of the amount in two ways. In rare instances the fuller statement may be of interest to a purchaser. Unfortunately, the Act does not limit the number of times and ways the manufacturer may state the same thing in the guarantee, and consequently he is within his rights in multiplying the number. The purchaser, however, will do well to remember that no matter how complex the guarantee may be the valuation should be made on the three items: (1) "nitrogen," (2) "available phosphoric acid," and (3) "potash." This fact is recognized in the concise statement used in speaking of a fertilizer as being a 3-6-10. The meaning is that it contains 3 per cent. of nitrogen, 6 per cent. of phosphoric acid, and 10 per cent. of potash.

Trade Names

The need of a guarantee is emphasized by the great number of different brands of fertilizers on the market. The trade name given a particular brand is usually an indication of the crop to which it should be applied, as "Potato Manure," "Grape and Small Fruit Special," "Orchard Special," "Tobacco Grower," etc. Doubtless these preparations are well adapted to the requirements of the plants, but it is impossible to make any one mixture that will give the best results with all kinds and conditions of soils. The trade named substances are useful and are an attempt to furnish a fertilizer that is properly balanced for the particular crop named. This, however, does not mean that any fertilizer named for a particular crop will under all conditions give the best results.

To use fertilizers intelligently it is absolutely necessary that a study be made of the fertilizers themselves and the crop and soil requirements. The first can only be got by studying the literature on the subject and by observation. The second can be best got by reading and experimenting.

CALCULATION OF THE VALUE OF FERTILIZERS.

The true money value of fertilizers cannot be estimated. This would be measured by the increased crop produced and it is manifestly impossible to fix a value to any fertilizer which would be correct under the varying conditions of climate, soil, crop, season, and method of use. It is important, however, for

the farmer when purchasing a fertilizer to have some system of calculation whereby he may be able to tell whether that fertilizer is selling at a price according to its true market value, or not. In other words, he should know if he is getting his money's worth according to the trade value. In the case of purely mineral fertilizers it is evident from previous reading that the value depends upon the amount and condition of the nitrogen, phosphoric acid and potash present. Now, if we consider a simple mineral fertilizer like nitrate of soda, which we buy for the nitrogen it contains, it is readily seen that according to the market price of this mineral we can fix a "unit value" for nitrogen. Any unit may be taken, but the unit most conveniently adopted in the trade is stated as being one per cent., on the basis of a ton, or 20 pounds. Thus, if nitrate of soda containing 15 per cent. of nitrogen is selling at $55.00 per ton, the price of a unit of nitrogen is found by dividing $55.00 by 15 per cent.=$3.66 per unit.

Similarly, superphosphate selling at $16.00 per ton and containing 16 per cent. available phosphoric acid gives the price for a unit of available phosphoric acid at $\frac{16}{16}$=$1.00 per unit.

Again, muriate of potash selling at $41.80 per ton and containing 48 per cent. potash gives the price for a unit of potash at $\frac{41.80}{48}$=87c. per unit.

According to these calculations we have the following unit values:

Nitrogen	$3.66 per unit.
Available phosphoric acid	1.00 " "
Potash	.87 " "

Knowing a value for each of these units we can now readily estimate from the guaranteed analysis which accompanies a fertilizer whether it is being offered for sale at a legitimate price, or not.

Two potato manures of the following composition, respectively, are placed on the market at the prices mentioned, and it is required to ascertain which is better value.

No. I.

Price $32.00 per ton.

Analysis:	Nitrogen	4 per cent.
	Available phosphoric acid	8 " "
	Potash	10 " "

No. II.

Price $30.00 per ton.

Analysis:	Nitrogen	2 per cent.
	Available phosphoric acid	6 " "
	Potash	12 " "

From the above unit values the value of these two fertilizers would be estimated as follows:

I.	Nitrogen	4 per cent., or 4 units, at $3.66 =	$14.64
	Available phosphoric acid	8 " " " 8 " " 1.00 =	8.00
	Potash	10 " " " 10 " " .87 =	8.70
		Actual value per ton =	$31.34
		Price charged per ton =	32.00
II.	Nitrogen	2 per cent., or 2 units, at $3.66 =	$7.32
	Available phosphoric acid	6 " " " 6 " " 1.00 =	6.00
	Potash	12 " " " 12 " " .87 =	10.44
		Actual value per ton =	$23.76
		Price charged per ton =	30.00

No. 1 is satisfactory value at $32.00 per ton, while No. 2, although offered at a lower price, is still $6.24 above the actual value.

Many farmers make the mistake of assuming that a manure of a low price is economical. This, however, is not necessarily the case; indeed, it is usually found that the high-grade manures are in reality the cheaper when valued according to their composition.

Unit Values.

In making a valuation of any fertilizer it should be thoroughly understood that the unit prices for Nitrogen, Phosphoric acid and Potash are based entirely on the market values of the raw fertilizers supplying but one of these plant food elements. These unit values may vary in the different raw fertilizers according to their percentage, composition and price, as follows:—

Unit Values of Nitrogen.

Fertilizer	†Price per ton.	% Nitrogen or Units of Nitrogen in one ton.	Price per Unit of Nitrogen.	Condition or kind of Nitrogen.
Nitrate of Soda	$55 00	15	$3 66	Nitrate
Sulphate of Ammonia	70 00	19	3 68	Ammonia
Calcium Cyanamid	48 00	15	3 20	Organic
Dried Blood Meal	55 00	11	5 00	Organic

The unit value of organic nitrogen may be obtained from other manures such as Meat Meal and Tankage. which are sold chiefly for their nitrogen content. One per cent. ammonia is equivalent to four-fifths of one per cent. of nitrogen. Thus, if the nitrogen is stated as per cent. of ammonia, to convert to per cent. nitrogen multiply by 4-5, or more accurately .823.

Unit Values of Soluble or Available* Phosphoric Acid.

Fertilizer.	†Price per ton	% Phosphoric acid, or units, in one ton.	Price per unit of phosphoric acid.	Conditions or kind of phosphoric acid.
Superphosphate	$16 00	16	$1 00	Acid
Basic Slag	18 00	12	1 50	Basic or Alkali

Unit Value of Insoluble or Slowly Available Phosphoric Acid.

A unit value for insoluble phosphate in the organic form can be obtained from the price of bone meal containing 2.5 per cent., or units of nitrogen, and 23 per cent. or units of insoluble phosphoric acid, at $30.00 per ton. 2.5 units of nitrogen at the highest unit value (in the organic form) would be $3.68 per unit = $9.20. Subtracting this from $30.00 ($30.00—$9.20) = $20.80 for 23 units of Phosphoric acid; = 90 *cents per unit of insoluble organic phosphoric acid*

The market price of Ground Rock Phosphate would establish a unit value for insoluble mineral phosphate which has not been treated with strong acid. Though this kind of phosphate is a popular fertilizer in some places, as yet it is rarely used in Ontario and the price is seldom quoted at present.

* By available phosphoric acid is meant that which is soluble in water or very weak acid. In the case of a phosphate fertilizer which has been treated with very strong acid the phosphate which remains insoluble is considered of little or no value.

Unit Values of Potash.

Fertilizer.	†Price per ton	% Potash, or units in one ton.	Price per unit of potash.	Condition or kind of potash.
Sulphate of Potash	$50 30	47	$1 07	Sulphate
Muriate " "	41 80	48	87	Muriate or Chloride

From the study of the use of the different kinds of Nitrogen, Phosphoric Acid and Potash which has already been given, it will be realized that the fertilizer supplying the cheaper unit value is not necessarily the best to use. Each fertilizer has its own particular use which should be considered in conjunction with its cost.

OBJECT OF EXPERIMENTING WITH FERTILIZERS.

The proper and profitable use of fertilizers will only come with considerable experience. There is no better way for the farmer to familiarize himself with the peculiarities of his soil, the characteristics of his crops and the various constituents of fertilizers than by actual experiments. Considering all the different conditions existing it is unwise for the farmer to use large quantities of these expensive materials without proving that they will give profitable results. These experiments may be of a very simple nature and the time and labor required in conducting them is practically negligible. An examination of soil in the laboratory often provides valuable information on which to base experiments and the results of fertilizer applications on similar soils are a useful guide. In practice, however, no two soils of the same class are found exactly alike, and each field may be looked upon as having its own peculiarities. Hence, it is most important that the farmer should find out what is the best and most profitable treatment on his own farm.

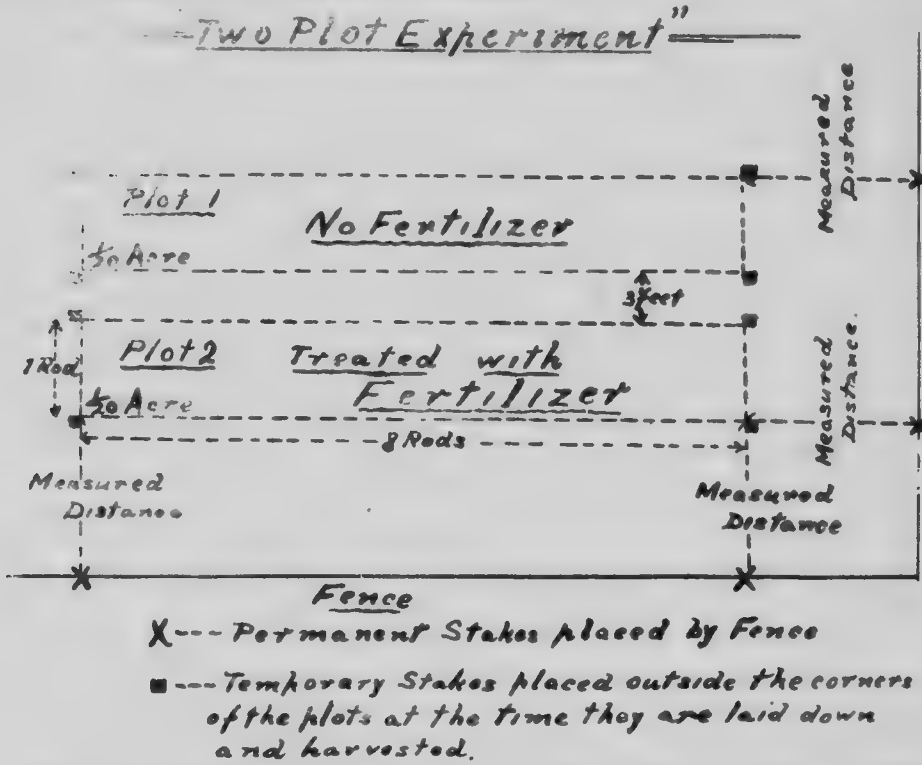
Furthermore, when the experiments include the use of the simple materials such as nitrate of soda, muriate of potash and superphosphate, the experimenter becomes familiar with the fact that he is dealing with three distinct constituents of plant growth. It is to be feared that in many cases purchasers of mixed fertilizers do not fully realize the fact and buy the material more from the name it bears than from any definite knowledge of the amount of nitrogen, phosphoric acid and potash that may be in the fertilizer. Again, carefully conducted experiments enable the experimenter to note the effect of the different constituents upon the growth of the crops. This in itself is valuable, because it helps him to form some idea of the needs of a growing crop from its appearance.

In this way the experiments not only help to make clear the peculiarities of soils and crops, but they also aid the experimenter to become more familiar with the fertilizers themselves. Thus, properly conducted experiments should lead to the more intelligent and economical use of these expensive materials.

† The above prices were quoted in the spring of 1914 for ton lots from the Toronto warehouses. These prices may vary considerably each year, and in different places, and the farmer should calculate the unit values accordingly.

HOW TO EXPERIMENT WITH FERTILIZERS.

The important question in using any fertilizer is "Will it pay?" This can always be answered by a simple "Two Plot Experiment." The details of conducting such an experiment are as follows: Select a uniform area of soil and carefully measure out two plots as illustrated.



The exact position of the plots in the field should be noted by measured distances from the corners of the plot to permanent stakes by the fence, as shown. Stakes left at the corners of the plot invariably become misplaced through intertillage during the growing seasons and being unnoticed may cause damage to harvesting implements. The plots should be a sufficient distance from the fences of the field so as to be free of the headlands and well away from any trees. Keep the boundaries of the plots at right angles. There should be a dividing strip between each plot, so that the treatment of one plot will not be contaminated with that of another and the results will be entirely separate. The size of the plots may vary according to the convenience of the experimenter, but one-twentieth or one-tenth of an acre is usually most satisfactory for farm crops. If no platform scales large enough to take a waggon or cart is available, the difficulties of dealing with the harvest of large areas are too great. With small areas, greater accuracy is required owing to the multiplication of any errors in calculating quantities per acre. Fertilizer plots with vegetables and market garden produce may be very small. The shape of the plots should be long and narrow rather than square so as to ensure a better uniformity of soil. Where the crop is in drills particular attention should be taken to see that the same number of rows are in each plot.

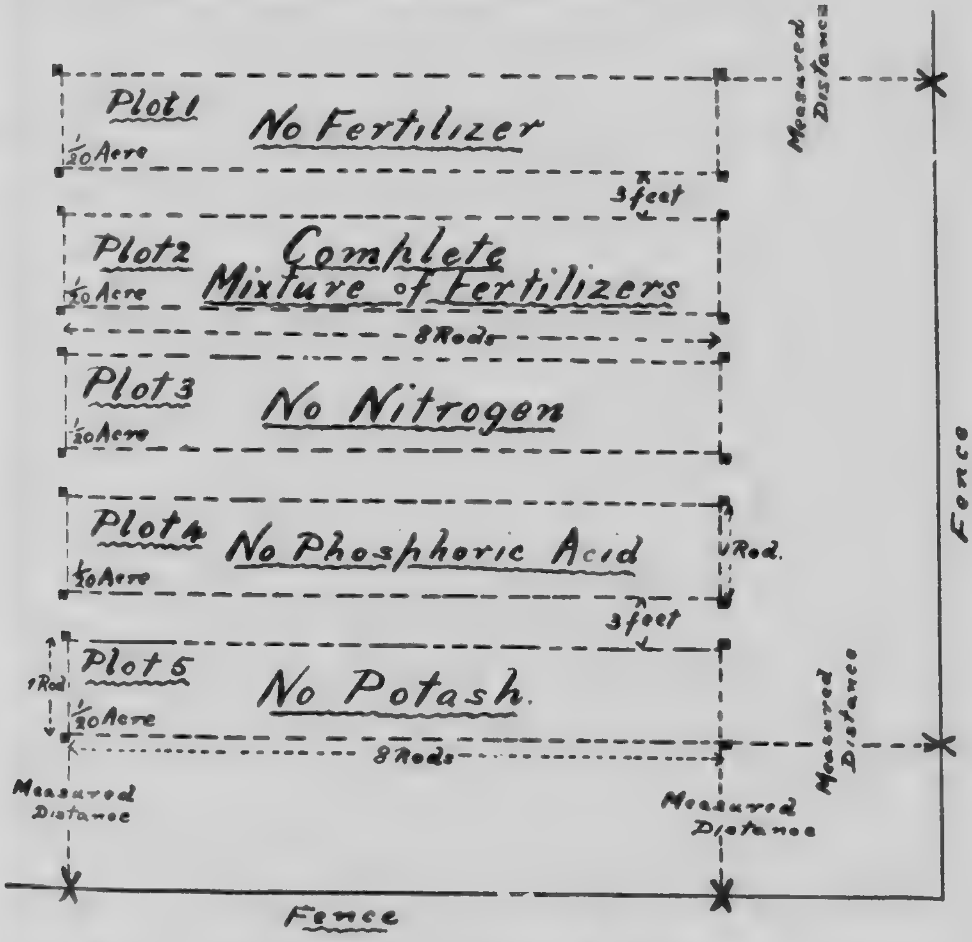
Regarding the "Two Plot Experiment" under discussion, both plots are prepared in exactly the same manner, receiving an application of farmyard manure

... e rest of the field. Plot No. 1 receives no fertilizer and is a check result ... untreated land identical to Plot No. 2, which receives the dressing of fertilizer.

This experiment should simply prove whether the fertilizer being tested was profitable to use or not for that particular soil and crop. In judging the result it should not be forgotten that an increased yield does not necessarily mean an increased profit. The cost of the fertilizer and its application should be deducted, though apart from this very little more expense is entailed in dealing with a maximum as compared with a minimum crop.

The "Two Plot Experiment" is best suited to the testing of any complete fertilizer mixture containing nitrogen, phosphoric acid and potash. If, however, ... detailed information is required regarding the deficiency of a soil in one

"Five Plot Experiment"



X --- Permanent Stakes by Fence

■ --- Temporary Stakes placed outside the corners of the plots at the time they are laid down and harvested

or more plant food constituents we would recommend the "Five Plot Experiment" here illustrated and laid with the same detail as previously mentioned.

Plot 1, is a check receiving no fertilizer.

Plot 2, receives a complete mixture of nitrogen, phosphoric acid and potash at the rate of:

	Per Acre.	1/20 Acre.
Sulphate of Ammonia	150 lbs.	7½ lbs.
Superphosphate	400 "	20 "
Muriate of Potash	150 "	7½ "

Plot 3, receives a mixture of phosphoric acid and potash only, at the rate of:

	Per Acre.	1/20 Acre.
Superphosphate	400 lbs.	20 lbs.
Muriate of Potash	150 "	7½ "

Plot 4, receives a mixture of nitrogen and potash only, at the rate of:

	Per Acre.	1/20 Acre.
Sulphate of Ammonia	150 lbs.	7½ lbs.
Muriate of Potash	150 "	7½ "

Plot 5, receives a mixture of nitrogen and phosphoric acid only, at the rate of:

	Per Acre.	1/20 Acre.
Sulphate of Ammonia	150 lbs.	7½ lbs.
Superphosphate	400 "	20 "

Sulphate of Ammonia is recommended as a source of nitrogen in this experiment because it is more suitable for mixing with Superphosphate and Muriate of potash, and all the fertilizers can be applied in one operation.

The results of a "Five Plot Experiment" show whether a complete mixture of nitrogen, phosphoric acid and potash, or a mixture of any two of these ingredients is most profitable in the proportions used. The leaving out of nitrogen, phosphoric acid and potash in Plots 3, 4 and 5, respectively, will also show which of these constituents is most needed for that particular soil and crop. The proportions in future applications can thus be adjusted so that the plant food most needed for the same soil and crop will suitably predominate in the mixture.

In every case, however, the main principle of the successful use of fertilizers should not be forgotten, namely, *Fertilizers cannot take the place of Farmyard Manure but are merely to supplement its deficiencies in supplying the right proportion of available plant food. Never discard Farmyard Manure for the use of fertilizers entirely, but, whenever possible use the two together. If Farmyard Manure cannot be obtained every effort must be made to supply organic matter by means of catch crops plowed in as green manure.*

MIXING OF FERTILIZERS.

From what has been said it will be realized that as the farmer's knowledge of fertilizers increases, especially through experimenting, the more he will desire to apply fertilizers according to the requirements which he finds necessary in his own practice. He will naturally prefer to use the simple fertilizers and to make up his own mixtures in the proportions which his experiments demonstrate to be most profitable. In some instances he may find that an application of only one or two plant food constituents produces the greater profit. Very often the expensive nitrogenous fertilizers can be economically dispensed with. This is

especially true where leguminous crops have been largely used in the rotation, thereby increasing the nitrogen content of the soil, as previously described. Thus, providing the farmer sufficiently understands the use and properties of the simple fertilizers, it is a decided advantage to make up his own mixtures according to the requirements of his soil and crops. Home made mixtures can be made up at a minimum cost. The nature and availability of fertilizers can be considered in making up a mixture. A farmer knowing exactly what he is applying is enabled to read his results more intelligently and to improve future applications.

There is no reason whatever why the farmer should not use Tankage, Dried Blood and other offal from the pork-packing and slaughter houses as a basis in mixtures and as a source of organic nitrogen and phosphate.

How to Mix Fertilizers

It is highly important that fertilizers be thoroughly mixed. Unless a farmer is prepared to carry out the work efficiently home mixing will prove a failure. In mixing manures the following directions should be followed: Select a clean, dry floor, preferably of concrete, and spread out the fertilizers in the required proportions in a heap. By means of a broad shovel turn the heap completely several times until thoroughly mixed and crush finely any lumps. The mixture should be finally passed through a fine riddle or screen (of one-eighth inch mesh) such as is used for sifting sand or gravel in making cement. Should a mixture form only a small quantity to cover a large area, the bulk should be increased to at least half a ton per acre by adding a quantity of sand or fine dry earth. This ensures more even distribution on applying.

Fertilizers Which Should Not be Mixed.

Some manures cannot be mixed on account of chemical action being thereby set up which results in a loss or depreciation of the fertilizing ingredients. To avoid this trouble do not mix the following:

1. Lime, wood ashes or basic slag with any manure containing ammonia, such as Sulphate of Ammonia, Farmyard Manure, or any organic manure.
2. Lime, Wood Ashes or Calcium Cyanamid with any fertilizer containing soluble phosphate, such as Superphosphate or Dissolved Bones.
3. Nitrate of Soda with Superphosphate or Dissolved Bones, except for immediate application, and under no circumstances if the Superphosphate or Bones are not in a fine dry condition.
4. When fertilizers of a crystalline nature like the potash salts are mixed with Superphosphate or Basic Slag, a hard, cement-like mass is likely to result if the mixture is not spread within a few hours. This can be avoided by adding a quantity of sawdust, dry peaty material, or earth.

APPLICATION OF FERTILIZERS.

The successful use of fertilizers depends largely on the method of application. Uniformity and evenness of distribution on the land is all important. It is common where Nitrate of Soda has been used as a top dressing to see lines or patches of darker green and stronger growth, especially in the case of a hay or cereal crop. This is due to the uneven distribution of the supply of nitrogen and

represents where the Nitrate of Soda fell thicker during the process of sowing. To obtain even distribution by hand it is necessary to increase the bulk of fertilizer to at least 10 cwt. per acre by adding sand, fine earth or ashes and to divide the mixture into two parts. Application is then accomplished in like manner to the sowing of seed broadcast, one part of the mixture being sown lengthwise and the other part crosswise.

The use of a machine for sowing fertilizers will always accomplish better and quicker work. There should, however, be sufficient work of the kind on the farm to justify the expense of such a purchase. Many types of machines are made and nearly all work well, provided the fertilizers are fine and dry. Those machines, however, which possess moving parts working in the fertilizers are very apt to clog when sowing mixtures of a wet or sticky nature.

Sowing fertilizers broadcast is as a rule preferable to sowing in the drill. Broadcasting is quicker and brings about more even distribution. Thus, the crop grows more uniform and healthy with more extensive root, than when the manure is concentrated immediately under the plants.

When to Apply Fertilizers.

Broadly speaking, the time of application will depend upon the nature of the fertilizer, together with the use for which it is required and the nature of the crop.

Farmyard manure and insoluble organic fertilizers in general can be applied with advantage in the late fall. Before these can become available to the plant they must undergo a process of decomposition or decay. By applying in the fall there is not only a saving of time in the spring, but decomposition sets in without delay and the possible benefits to be derived that season are thereby increased. To obtain the full action of Lime and Basic Slag during the next season their application is also made in the fall.

Usually all soluble fertilizers are applied in the spring. Except in the case of Nitrate of Soda, the best time is about two weeks before seeding or planting. This will permit of the fertilizers being thoroughly mixed with the soil during the working up of the seed bed and any injurious effects which accompany immediate application are avoided.

In order to reduce loss by leaching to a minimum, Nitrate of Soda is best applied as a top dressing after the young plants have appeared above ground and when the growth needs stimulating.

Always select a calm day for sowing fertilizers. Early morning and sundown when the wind is low are the most suitable times.

INDEX.

LIST OF BULLETINS

PUBLISHED BY THE ONTARIO DEPARTMENT OF AGRICULTURE, TORONTO.

Serial No.	Date.		Title.	...thor.
175	Dec.	1909	Farm Drainage Operations	W. H. Day.
176	Dec.	1909	Bacterial Blight of Apple, Pear and Quince Trees	D. H. Jones.
177	Dec.	1909	Lime-Sulphur Wash	H. L. Fulm... / L. Cæsar.
178	Dec.	1909	Character and Treatment of Swamp or Muck Soils	W. P. Gamb... / A. E. Slate...
179	Feb.	1910	Fruits Recommended for Ontario Planters (No. 147 revised)	Fruit Branch
180	April	1910	Flour and Breadmaking	R. Harcourt. / M. A. Purdy.
181	June	1910	The Teeth and Their Care	Ont. Dental ...iety.
182	July	1910	Bee-keeping in Ontario	Fruit Branch
183	Aug.	1910	Notes on Cheddar Cheese-making	Dairy Bran...
184	Nov.	1910	Uses of Vegetables, Fruits and Honey	....
185	Nov.	1910	Little Peach Disease	L. Cæsar.
186	Dec.	1910	Children: Care and Training	J. J. Kelso.
187	Jan.	1911	The Codling Moth	L. Cæsar.
188	April	1911	Weeds of Ontario (No. 128 revised)	J. E. Howitt
189	May	1911	Farm Poultry (No. 151 revised)	W. R. Graham
190	May	1911	Bee Diseases in Ontario	Fruit Branch
191	June	1911	Bee-keeping in Ontario	Fruit Branch
192	July	1911	Agricultural Co-operation	S. E. Todd.
193	Nov.	1911	Tuberculosis of Fowls	S. F. Edwards
194	Dec.	1911	Apple Orcharding	Fruit Branch
195	Jan.	1912	Insecticides and Fungicides (No. 154 revised)	R. Harcourt. / H. L. Fulm...
196	Jan.	1912	Tomatoes	A. G. Turn...
197	Feb.	1912	Bee Diseases in Ontario	Morley Petti...
198	Feb.	1912	Lime-Sulphur Wash	L. Cæsar.
199	Feb.	1912	Onions	A. McMeans.
200	April	1912	Fruit Juices	L. Meunier.
201	May	1912	Peach Growing in Ontario / Peach Diseases	F. M. Cleme... / L. Cæsar.
202	May	1912	Grape Growing in Niagara Peninsula	T. B. Revett
203	May	1912	Cabbage and Cauliflower	A. McMeans.
204	June	1912	Decay of the Teeth	Ont. ...ntal Society
205	Sept.	1912	Dairy School Bulletin (No. 172 revised) I. Cheese-Making and Butter Making	Staff of Dairy School.
206	Nov.	1912	Dairy School Bulletin (No. 172 revised) II. Dairying on the Farm	Staff of Dairy School.
207	Dec.	1912	Ice-Cold Storage on the Farm	R. R. Graham
208	Jan	1913	Farm Poultry and Egg Marketing Conditions in Ontario County	J. H. Hare. / T. A. Benson
209	Mar.	1913	Farm Forestry (No. 155 revised)	E. J. Zavitz.
210	Mar.	1913	Strawberry Culture and The Red Raspberry	F. M. Clemen...
211	Mar.	1913	Fruits Recommended for Ontario Planters (No. 179 revised)	Fruit Branch
212	April	1913	Orchard Surveys in Dundas, Stormont and Glengarry	F. S. Reeves
213	April	1913	Bee Diseases in Ontario	Morley Pettit
214	May	1913	Sheep Raising in Ontario: Does it Pay?	Live Stock B...nch.
215	Aug.	1913	Demonstration Lectures in Domestic Science, Sewing and Nursing	Institutes Br...h.
216	Oct.	1913	Box Packing of Apples	E. F. Palmer
217	Dec.,	1913	Farm Poultry (No. 189 revised)	W. R. Graha... / A. C. McCull...
218	Dec.	1913	Birds of Ontario (No. 173 revised)	C. W. Nash.
219	Jan.	1914	The San José and Oyster-Shell Scales	L. Cæsar.
220	Mar.	1914	Lightning Rods	W. H. Day.
221	April	1914	F...d Value of Milk and its Products	R. Harcourt.
222	April	1914	Cu...ants and Gooseberries	E. F. Palmer.
223	May	1914	Fer...ilizers	R. Harcourt. / A. L. Gibson.